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Year: 2013

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**Re: Anatomical reconstruction of the lateral ligaments using Gracillis tendon in chronic ankle instability; a new technique [Foot Ankle Surg 2011;17(4):239-46].**

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DOI: <https://doi.org/10.1016/j.fas.2012.10.004>

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ZORA URL: <https://doi.org/10.5167/uzh-91566>

Journal Article

Accepted Version

Originally published at:

Klammer, Georg; Espinosa, Norman (2013). Re: Anatomical reconstruction of the lateral ligaments using Gracillis tendon in chronic ankle instability; a new technique [Foot Ankle Surg 2011;17(4):239-46]. Foot and Ankle Surgery, 19(2):141.

DOI: <https://doi.org/10.1016/j.fas.2012.10.004>

1                   **PERCUTANEOUS LATERAL ANKLE STABILIZATION**  
2                   **AN ANATOMICAL INVESTIGATION**  
3  
4

## ABSTRACT

**Background:** The current study investigates the topographic anatomy of the percutaneous anatomical lateral ankle stabilization in relation to the neurovascular hindfoot structures.

The study should serve as an aid for planning and performance of this new minimal invasive technique.

**Materials and Methods:** Eleven cadaver specimens were dissected exposing the nerves, vessels, ligaments and tendons. The portals and transosseous tunnels were performed by using K-wires. All distances of the K-wires and the neurovascular structures were measured with reference to clearly identifiable bony landmarks.

**Results:** On the medial side the average distance of the K-wire to the medial calcaneal branch of the tibial nerve was found to be 7mm (SD+/- 4). The medial calcaneal branch was hit twice by the transosseous K-wire. On the lateral side the mean distance of the fibular exit point of the K-wire to the sural nerve was 13 mm (SD+/-4). The closest distance of the superficial peroneal nerve to the footprint of the ATFL averaged 11.5mm (SD+/-3) and its anterior location in relation to the tip of the fibula 28mm (SD+/-8). The posterior tibial artery in relation to the perforating K-wire was found at a mean distance of 41mm (SD+/-6).

**Conclusion:** The current study introduces a novel percutaneous approach to treat chronic ankle instability that has minimal risk to neurovascular structures in a cadaver model. Further clinical studies must be undertaken to identify whether this technique would also be superior when compared with open surgery.

## 28 INTRODUCTION

29 Nonoperative measures yield successful results in about 80% of patients suffering from  
30 chronic ankle instability<sup>9</sup>. However, there are still some patients who continue to experience  
31 recurrent ankle sprains or some kind of “giving-way” at their ankle frequently combined with  
32 pain. Young and middle-aged patients who have failed a nonoperative treatment may be  
33 candidates for surgical repair. The goals of surgical repair are restoration of stability,  
34 elimination of pain and prevention of early ankle arthritis. Surgical strategies include  
35 anatomic (Brostrom)<sup>3</sup> and nonanatomic (Chrisman-Snook)<sup>5,21</sup> procedures. Since its first  
36 description by Brostrom<sup>3</sup>, the anatomic reconstruction of the lateral ankle ligaments has  
37 become the preferred treatment in order to achieve more physiologic kinematics at the  
38 hindfoot. Anatomical reconstruction can either be done by direct ligament repair or using  
39 tendon grafts (plantaris or gracilis tendon)<sup>6,12,20,27</sup>. The latter mainly preferred in case of  
40 absence of viable ligamentous tissue. While open surgery has become popular with good-to-  
41 excellent results in more than 80% of patients<sup>6</sup> not much is known about percutaneous  
42 techniques to stabilize the ankle. A percutaneous approach theoretically avoids the  
43 necessary dissection associated with open surgery and is thought to reduce peri- and  
44 postoperative morbidity and complications (e.g. injuries to the sural and superficial peroneal  
45 nerves; wound healing problems and infection; excessive and painful scarring)<sup>2,22,26</sup>.  
46 Sensory nerve injury can result in a painful and debilitating neuroma or loss of sensation both  
47 which could significantly impair quality of life and result in trophic disturbances.

48 More recently a percutaneous but anatomic technique to reconstruct the lateral ankle  
49 ligaments by means of a hamstring auto- or allograft has been described<sup>15</sup>. Scientific  
50 evidence that could speak in favour of this technique is lacking.

51 The key to any percutaneous approach is a thorough understanding of the superficial and  
52 deep anatomy. While open approaches allow direct visualization of the anatomical structures  
53 percutaneous techniques do not and the surgeon acts almost blindly potentially endangering  
54 the neurovascular structures of the hindfoot.

55 It would be preferable to know the proximity of the percutaneous approaches in relation to  
56 important neurovascular structures and how to avoid them during surgery.

57 The present cadaver study describes the topographic anatomy of the percutaneous  
58 approach in relation to the neurovascular structures and with respect to well-defined and  
59 reproducible anatomical landmarks – the fibular tip and the medial malleolus.

60 *We hypothesize that a percutaneous approach would not harm neurovascular structures.*

61

62

## MATERIALS AND METHODS

For the purpose of this study eleven cadaver-legs (5 left, 6 right) -provided by the Institute of Anatomy of the University- were used. All specimens were obtained from adults above 60 years. None of the subjects had a history of trauma or prior surgery at the ankle or evidence of musculoskeletal disease.

## TECHNICAL ASPECTS OF THE SURGICAL PROCEDURE

*For the percutaneous anatomical lateral ankle ligament reconstruction (Figure 1) a gracilis graft was used<sup>6,9</sup>. The first mini skin incision (5mm) was made at the anterior margin of the fibula approximately 10-15mm above the fibular tip. Under fluoroscopic control a guide wire was inserted at the insertion site of the anterior talofibular ligament (ATFL at the talar neck-head junction, approximately 18mm superior to the subtalar joint line) on the talus. Along the guide wire a 20mm long talar bone tunnel has been created using a 5mm cannulated drill bit. The guide wire was removed and the tendon graft inserted into the talar bone tunnel and secured by means of an absorbable interference screw. Next, the fibular bone tunnel was made using either a 4.5mm or 5.0mm drill bit directed from anterior to posterior. Adjacent to the posterior margin of the fibula but at the same level of the anterior portal the second skin incision was made. The free end of the graft was prepared by means of simple Krackow-stitches and pulled from anterior to posterior through the fibular bone tunnel exiting through the second skin incision. In case of a large and wide fibula a second bone tunnel could be considered pointing towards the fibular tip. The third skin incision was made over the expected insertional site of the calcaneofibular ligament (CFL) on the calcaneus (at the small tubercle posterior and superior to the peroneal tubercle of the calcaneus, 13mm distal and posterior to the subtalar joint line) (Figure 2). A third drill hole was made at the insertional site of the CFL. The drill hole ran from lateral through the medial calcaneal wall. By blunt preparation the tendon graft was pulled from the second through the third incision ensuring that it ran underneath the peroneal tendons. The graft was then inserted into the calcaneal bone tunnel and pulled from lateral through medial by aid of a suture passer. Holding the*

hindfoot in neutral position the graft was secured in the calcaneal bone tunnel under adequate tension (the reconstructed ATFL and CFL should be straightened and tightened while holding the ankle in neutral position) with an absorbable interference screw.

## **MEASUREMENTS**

In order to measure the distances of structures in relation to the surgical approach the operative procedure was simulated using guide-wires to mark the insertion tunnels in the talus and calcaneus as well as the drill hole through the fibula. The senior author carried out all dissections. The medial and lateral malleolar tips served as reference landmarks in this study because they were easily palpable and identifiable. First an L-shaped skin incision starting close to the Achilles tendon and extended parallel to the plantar aspect of the foot was performed. The cutaneous skin flap was removed while carefully exposing the branches of the lateral and medial trunk of the superficial peroneal nerve. Medially, the skin was removed in a similar fashion to the lateral side. The posteromedial neurovascular bundle (tibial nerve and the posterior tibial artery) was identified posterior of the tip of the medial malleolus and the branches of the tibial nerve were dissected proximally to their origin and distally to their terminal digital branches. The size of the sinus tarsi orifice was measured in two dimensions. The lateral malleolus and the locations of the ATFL and CFL were noted in all specimens. Distances were measured using a manual calliper.

The following distances were recorded:

- The shortest distance between the superficial peroneal nerve to the anterior margin of the fibula at the point of its penetration through the deep fascia.
- The shortest distance between the superficial peroneal nerve and the lateral malleolar tip.
- The shortest distance between the superficial peroneal nerve and the ATFL.
- From the sural nerve to the most dorsal aspect of the lateral malleolus and to its tip respectively.

119       • The anteroposterior, mediolateral and vertical distances from the posterior fibular exit  
120       point of the K-wire to the sural nerve.

121

122   On the medial side the following distances of the calcaneal exit point of the K-wire were  
123   measured:

124       • To the posterior tibial artery.

125       • To the medial and lateral plantar nerve.

126       • To the medial calcaneal branch of the tibial nerve.

127

128   Additionally we assessed the vertical distance between the K-wire exit point to the medial  
129   malleolar tip and the horizontal distance to the most posterior tibial aspect.

130



## RESULTS

In the eleven examined specimen all neurovascular structures could be identified.

A synopsis of the measured parameters including mean and standard deviations (SD) are given in Table 1. Figures 3A, 3B and 3C depict the structures and measurements.

In two of the eleven specimens the sural nerve crossed the fibular tip but was never injured by a K-wire. The medial calcaneal branch of the tibial nerve was found closest to the K-wire exit point (12) and was hit by the K-wire in two specimens.

## DISCUSSION

*The current work presents an anatomical study of a novel and minimal-invasive surgical technique of lateral ankle reconstruction. Although most of the investigated neurovascular structures were not injured the introduced percutaneous procedure still bears the potential to damage a branch of the tibial nerve. In this study we found the medial calcaneal branch of the tibial nerve to be at greatest risk while driving the guide wire latero-medially through the calcaneus. This is emphasized by the fact that in two of 11 specimens (18%) the medial calcaneal branch of the tibial nerve was hit by the K-wire*<sup>10</sup>. Damage to this nerve branch can result in a painful neuroma or loss of plantar protective sensitivity with ulcer formation as a possible sequel. Previous studies recognized the risk of iatrogenic damage to the medial neurovascular bundle during calcaneal pin placement<sup>1,4,16,17,19</sup>. The bundle includes the posterior tibial artery dividing into the medial and lateral plantar artery and the tibial nerve branching into the medial and lateral plantar nerve and the medial calcaneal nerve branch. The safest zone for calcaneal pin placement has shown to be the postero-inferior medial calcaneus, although the medial calcaneal nerve remains at risk<sup>4,17</sup>. *Considering the origins of the tibial nerve, medial and lateral plantar nerve*<sup>11</sup> and number of branches (1-4)<sup>7</sup> the medial calcaneal branch of the tibial nerve is highly variable. The probably most applicable definition of a safe-zone has been provided by Gamie et al.<sup>10</sup>. *They described four well palpable anatomical landmarks consisting of the inferior tip of the medial malleolus, the posterior superior portion of the calcaneal tuberosity, the navicular tuberosity, and the medial process of the calcaneal tuberosity. According to their measurements they defined the safest zone to be the calcaneal area found behind the line connecting the posterior superior calcaneal tuberosity and the medial process of the calcaneal tuberosity.* In order to minimize any lesion to the medial calcaneal branch of the tibial nerve we believe that it is important to aim at the above described safe-zone *and specifically pointing to the posterior-inferior and medial calcaneal wall.* One might argue whether the step of pulling the graft through the calcaneus is necessary or not. However, in our experience, this step is unavoidable in order to achieve adequate tension of the tendon graft. *An alternative way of fixation might avoid the medial*

neurovascular structures but this remains speculative and is beyond the scope of the present study.

The sural nerve was never found to be injured by the K-wires and the average distances to the posterior border of the fibula and its tip were comparable to those found in the literature<sup>14,18,22,24,25</sup>. However, in two of the 11 specimens the nerve crossed the distal tip of the lateral malleolus leaving it susceptible to possible injury in case the drill-bit is advanced too far posteriorly behind the fibula. It was found that in 21% the sural nerve had direct contact with the most posterior aspect of the fibula and that in 10% the nerve also revealed contact with the tip<sup>22</sup>. There are a high number of fibular branches and anastomoses between the superficial peroneal nerve and the sural nerve, which should also be appreciated and preserved when performing surgery at the lateral ankle region<sup>8,22</sup>.

In contrast to the situation of the medial calcaneal branch of the tibial nerve and sural nerve the superficial peroneal nerve showed not to be endangered regarding the surgical approaches. In a previous anatomical study three distinct branch patterns of the superficial peroneal nerves were found<sup>26</sup>. In 10% the superficial peroneal nerve revealed no division and had a similar course like the medial dorsal cutaneous nerve. As access to the lateral malleolus is necessary for lateral ankle ligament reconstruction the safe distance to the intermediate dorsal cutaneous nerve is of special interest. Fascial penetration of the intermediate dorsal cutaneous nerve varied remarkably<sup>26</sup>. Similar results were reported by Johnston and Howell in 68 specimen<sup>13</sup>. Some authors<sup>26</sup> found all branches to run anteriorly to the fibula, while others<sup>2</sup> identified in 16% a branching subtype with intermediate dorsal cutaneous nerve fascial penetration dorsal to the fibula crossing the fibula to continue anteriorly at an average of 4.5cm above the ankle joint. In such a case the branch of the superficial peroneal nerve could be injured by placing the anterior portal of the percutaneous approach. Solomon et al. observed a more oblique course of the nerve if it pierced the fascia farther distally making it more susceptible to injury through commonly used longitudinal skin incisions<sup>22</sup>. Others postulated a higher risk of tension neuropathy if fascia penetration occurs farther distally due to the nerves' reduced capacity compensating tensional or translational

forces<sup>13</sup>. The location of the intermediate dorsal cutaneous nerve on a line between the most prominent aspect of the medial and lateral malleolus was found at approximately 27mm (SD+/-9) (corresponding at 27.2% (SD+/-8)) from lateral<sup>26</sup>. In another study of 51 specimens branches of the superficial peroneal nerve lateral to the peroneus tertius were found in 11.8% and additional 27.5% at its edge. For this reason it was advised to make the incision for an anterolateral ankle arthroscopy portal at least 2mm lateral to the peroneus tertius<sup>23</sup>. Based on those findings and with proper handling of the soft-tissues damage to the superficial nerve could be reduced to a minimum. In the present study the superficial peroneal nerve was found to lie well anterior to the fibula and it was never injured. This study has some limitations. The major one is a relatively low number of specimens used for the measurements. Nevertheless, all measurements were done as precise as possible. The stiffness of soft-tissues in cadaver specimens is another problem and could influence measurements as well. However, we think that the values presented in the current work are of value and could help to guide surgeons in order to apply this novel technique. The risks of any neurovascular injury were minimal in this cadaver study. However, clinical data is still missing. Thus, further studies have to be performed to investigate any advantage of the percutaneous approach when compared with open surgery.

## LEGENDS TO THE FIGURES

Fig 1: Schematic drawing illustrating the anatomical lateral ankle ligament reconstruction using a gracilis autograft.

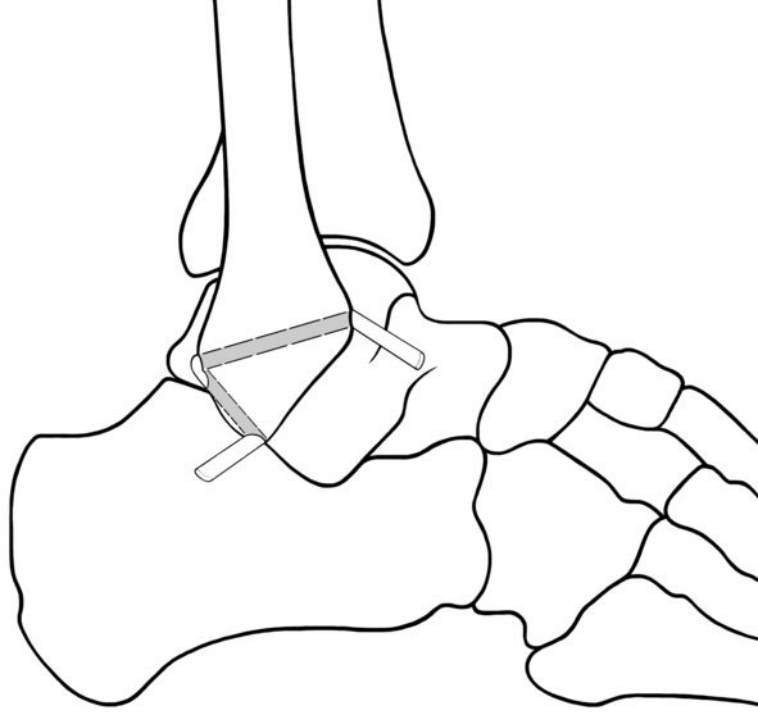
Fig 2: Intraoperative view demonstrating the placement of the three skin incisions. The course of the transfibular channel is marked on the skin (dotted line). The transplant has been passed below the peroneal tendons. A suture passer is now driven lateromedially through the calcaneus aiming toward the safe zone, allowing the insertion of the graft into the predrilled hole under correct tension.

Fig 3A-C: Lateral (A), anteroposterior (B) and medial (C) views of the ankle indicating the most important distances measured in percutaneous lateral ankle reconstruction. SN: Sural nerve; SPN: Superficial peroneal nerve; PTA: Posterior tibial artery; TN: Tibial nerve; LPN: Lateral plantar nerve; MPN: Medial plantar nerve; MCB: medial calcaneal branch of tibial nerve; ATFL: Footprint of the anterior talofibular Ligament.

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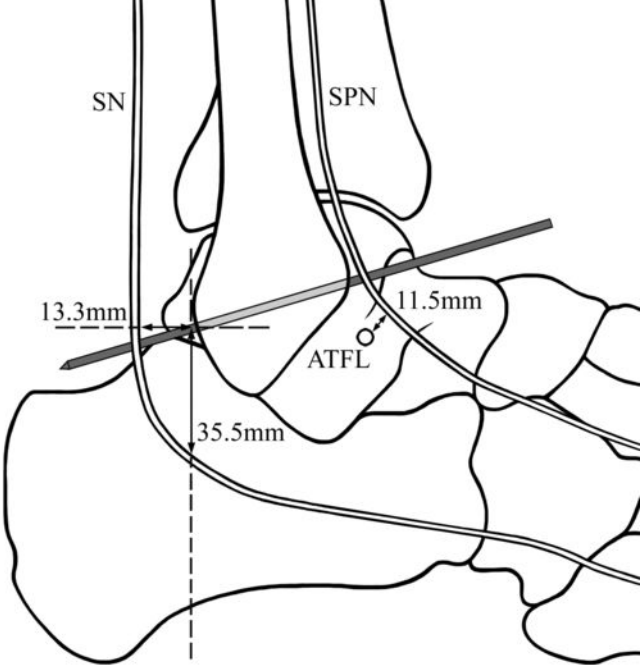
SPN

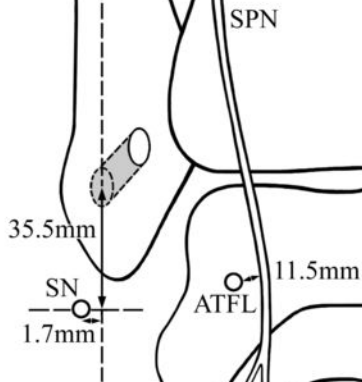
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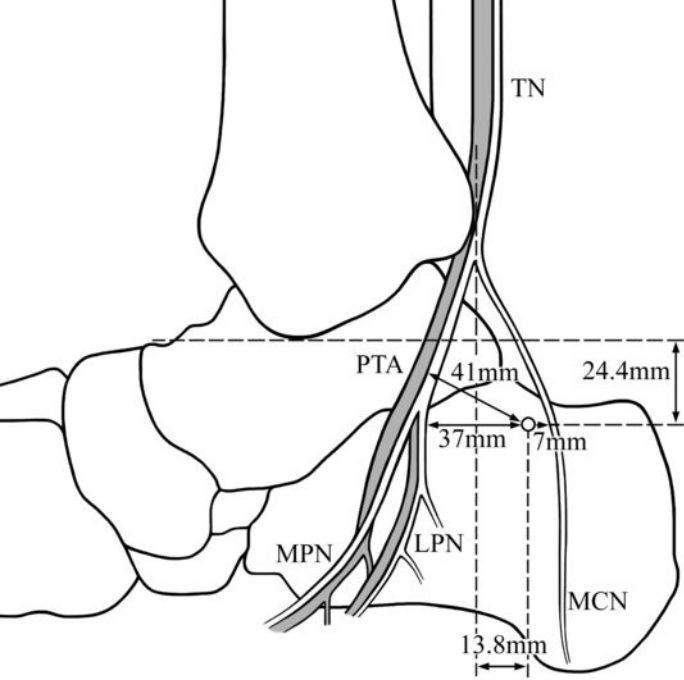
11.5mm

ATFL

35.5mm







PARAMETER	DISTANCE mm	SD +/-
<b><i>LATERAL SIDE</i></b>		
AP-width fibula	30.5	3
Lateral fibular cortex - intrafibular K-wire	2.6	0.5
Peroneus brevis tendon - posterior exit K-wire	27.2	5
Sural nerve – posterior fibular exit point of K-wire (vertical line)	35.5	3
Sural nerve – posterior fibular exit point K-wire (horizontal line)	13.3	4
Sural nerve - fibular tip (coronar plane)	1.72	1
<b><i>MEDIAL SIDE</i></b>		
K-wire - medial calcaneal nerve branch	7	4
K-wire - posterior tibial artery	41	3
K-wire - lateral plantar nerve	37	7
K-wire - posterior margin medial malleolus (horizontal line)	13.7	1

K-wire - posterior margin medial malleolus (vertical line)	24.4	1
<b><i>ANTEROLATERAL SIDE</i></b>		
Nervus per. sup.- ATFL origin (direct)	11.5	3
Nervus per. sup. – anterior fibular entry point of K-wire (horizontal)	40	2
Nervus per. sup. – fibular tip (direct)	28	6